Higgs search in TauTau final states @ CMS

Simone Gennai (CERN/INFN) on behalf of the CMS Collaboration
Outline

- Analyzed data
- Signal processes
- Event Categorization
- Tau ID
- Event selection
- Invariant mass distribution
- Limits
  - Reference: PAS-HIG-11-009
Collected/Analyzed Data

- Data delivered by LHC: 1.28 fb\(^{-1}\)
- Data recorded by CMS: 1.18 fb\(^{-1}\)
  - about 92%
- High quality data: 1.1 fb\(^{-1}\)
  - about 93%
- Analyzed data: 1.1 fb\(^{-1}\)
Production Mechanism

MSSM

SM

EPS-HEP 2011
# Categorization

- Limit based on the fit of the visible mass distribution
- To gain sensitivity event categories on the basis of extra jets

### Standard Model

**VBF**

- \# Jets (pT > 30 GeV) = 2
- AND
- VBF selections(*)

**NOT VBF**

- \# Jets (pT > 30 GeV) < 3
- OR
- Fails VBF selections

### MSSM

**bTagging**

- \# Jets (pT > 30 GeV) < 2
- AND
- \# btagged jets (pT > 20 GeV) > 0

**NOT bTagging**

- \# Jets (pT > 30 GeV) < 2
- AND
- \# btagged jets (pT > 20 GeV) = 0

* VBF : Mjj > 350 GeV, DeltaEtajj > 3.5, \eta_j1 \times \eta_j2 > 0
Jet variables

- Observed
- $Z \rightarrow \tau \tau$
- $t\bar{t}$
- Electroweak
- Fakes

EPS-HEP 2011
Hadronic Tau identification

- Reconstruction of the decay modes:
  - 1 prong, 1 prong + π0's, 3 prongs

- Various working points for the isolation

- Additional selections to reject electrons and muons
Tau ID efficiency

- Improved tau ID using Tag & Probe
  - BKG constrained from sidebands
  - See Mauro Verzetti poster for more information

Uncertainty’s source

<table>
<thead>
<tr>
<th>Source</th>
<th>Uncertainty</th>
</tr>
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<tbody>
<tr>
<td>Muon Momentum Scale</td>
<td>&lt;&lt; 1%</td>
</tr>
<tr>
<td>$\tau$-Jet Energy Scale</td>
<td>&lt; 1%</td>
</tr>
<tr>
<td>Track Reconstruction</td>
<td>3.9%</td>
</tr>
<tr>
<td>Track Momentum Scale</td>
<td>&lt; 1%</td>
</tr>
<tr>
<td>Lead. Track $P_T$ Cut</td>
<td>1%</td>
</tr>
<tr>
<td>Loose Isolation</td>
<td>2.5%</td>
</tr>
<tr>
<td>Jet $\to \tau_{had}$ Fakes</td>
<td>1.2%</td>
</tr>
<tr>
<td>Lead. Track Corr. Factor</td>
<td>1.7%</td>
</tr>
<tr>
<td>Loose Iso. Corr. Factor</td>
<td>2.1%</td>
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<tr>
<td>Fit (Statistical Uncertainty)</td>
<td>2.6%</td>
</tr>
<tr>
<td>Total uncertainty</td>
<td>6%</td>
</tr>
</tbody>
</table>

New! (was 23% for Winter conferences)
Event selections

- **Standard CMS Jet/MET/lepton reconstruction and selection**

- **Acceptance cuts:**
  
  **Mu+Tau**
  
  Muon $p_T > 15$ GeV, $|\eta| < 2.1$
  
  and
  
  Tau $p_T > 20$ GeV, $|\eta| < 2.3$

  **Ele+Tau**
  
  Ele $p_T > 20$ GeV, $|\eta| < 2.1$
  
  and
  
  Tau $p_T > 20$ GeV, $|\eta| < 2.3$

  **Mu+Ele**
  
  Muon $p_T > 20$ (10) GeV, $|\eta| < 2.1$
  
  and
  
  Ele $p_T > 10$ (20) GeV, $|\eta| < 2.5$

  **Mu+Mu**
  
  Lead muon $p_T > 20$ GeV, $|\eta| < 2.1$
  
  and
  
  Second muon $p_T > 10$ GeV, $|\eta| < 2.4$
Topological cuts

- Leptons are required to have opposite charge
  - e/mu+Tau and e+mu
    - Pzeta variable ("imported" from CDF) to suppress W+Jets
  - mu+mu
    - MET < 65 GeV
    - likelihood based selections using MET and muons related information
Background estimation

- **Data Driven**
  - QCD (mu+Tau, e+Tau)
  - Fake electrons bkg (e+mu)
  - Z->mumu (mu+mu)

- **MC shape + sidebands normalization**
  - Z->TauTau
  - TTbar
  - W+Jets (mu+Tau, e+Tau, e+mu)

- **Pure MC**
  - WW/ZZ/WZ
## Uncertainties table

<table>
<thead>
<tr>
<th>Source</th>
<th>Uncertainty</th>
<th>Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lepton ID /trigger</td>
<td>1%</td>
<td>Efficiency correction factors</td>
</tr>
<tr>
<td>Tau ID efficiency</td>
<td>6%</td>
<td>Efficiency correction factors</td>
</tr>
<tr>
<td>Tau energy scale</td>
<td>3%</td>
<td>Shape uncertainties</td>
</tr>
<tr>
<td>$\sigma(Z \rightarrow \mu\mu/ee)$</td>
<td>3%</td>
<td>$Z \rightarrow \tau\tau$ yield normalization</td>
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<tr>
<td>$\sigma(t\bar{t}bar)$</td>
<td>12%</td>
<td>TTBar yield normalization</td>
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<td>B-Tag Efficiency</td>
<td>10%</td>
<td>Correction factors</td>
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<tr>
<td>B-Tag Mistag rate</td>
<td>14%</td>
<td>Correction factors</td>
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<tr>
<td>Jet energy scale</td>
<td>2-5%</td>
<td>JEC in acceptance for BTagging/VBF</td>
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<tr>
<td>PDFs</td>
<td>3%</td>
<td>Uncertainty in cross section</td>
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<td>UE/Parton Shower</td>
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<td>Uncertainty in cross section</td>
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<td>QCD Scale</td>
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<td>Luminosity</td>
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MSSM
e/mu+Tau mass distributions

<table>
<thead>
<tr>
<th>final state</th>
<th>No Btag</th>
<th>BTag</th>
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</thead>
<tbody>
<tr>
<td>mu+Tau Bkg</td>
<td>14514</td>
<td>193</td>
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<td></td>
<td>+- 640</td>
<td>+- 13</td>
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<td>mu+Tau Data</td>
<td>15057</td>
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<td>e+Tau Bkg</td>
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<td>105</td>
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<td></td>
<td>+- 320</td>
<td>+- 9</td>
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<tr>
<td>e+Tau Data</td>
<td>10283</td>
<td>101</td>
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</table>
**e/mu+Tau mass distributions**

<table>
<thead>
<tr>
<th>final state</th>
<th>No Btag</th>
<th>BTag</th>
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</thead>
<tbody>
<tr>
<td>e+mu BKG</td>
<td>3643</td>
<td>150</td>
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<td></td>
<td>+- 131</td>
<td>+- 12</td>
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<td>e+mu Data</td>
<td>3942</td>
<td>143</td>
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<td>mu+mu BKG</td>
<td>15645</td>
<td>460</td>
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<td>+- 12</td>
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<tr>
<td>mu+mu Data</td>
<td>15711</td>
<td>479</td>
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</tbody>
</table>

**No B-Tag**
Jet1 pT = 177 GeV

Jet2 pT = 46 GeV

Tau pT = 69 GeV

Muon pT = 20 GeV

MET = 97 GeV

VBF
Mass distributions

<table>
<thead>
<tr>
<th>final state</th>
<th>VBF</th>
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</thead>
<tbody>
<tr>
<td>mu+Tau</td>
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<tr>
<td>BKG</td>
<td>+4</td>
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<tr>
<td>Data</td>
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<td>e+Tau</td>
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<tr>
<td>BKG</td>
<td>+/-2.5</td>
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<tr>
<td>Data</td>
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<td>e+mu</td>
<td>6.7</td>
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<td>BKG</td>
<td>+/-1</td>
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<tr>
<td>Data</td>
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<td>mu+mu</td>
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<td>BKG</td>
<td>+/-7</td>
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<td>Data</td>
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</tbody>
</table>
Conclusions

- MSSM limit MUCH improved wrt 2010 data
- First look at the SM limit: SigmaxBR < 10 x Standard Model
  - Doing 1.5x better than what we expected!
CMS has an advanced trigger system
- the HLT reconstruction allows a refined selection
- performance very similar to the offline
- Tau trigger rely already on the particle flow @ HLT!

Combined triggers looking for pairs of leptons allows to keep the thresholds low even in the presence of high luminosity and PU

- Mu+Tau
  - IsoMuon15 and IsoTau15
- Mu+Ele
  - Mu8 && Ele17 OR Mu17 && Ele8
- Ele+Tau
  - IsoElectron20 and IsoTau20
- Mu+Mu
  - IsoMu17
 Tau pT distribution 

CMS Preliminary
1.1 fb^{-1} \sqrt{s}=7 TeV
\tau_\mu \tau_h
(10x) H->\tau\tau \ m_H=120

- Observed
- Z->\tau\tau
- t\bar{t}
- Electroweak
- QCD
Background estimation

- **Z->TauTau**
  - MC based shape, with normalization taken from Z->ll CMS measurement (2%)
  - data driven normalization for event categories (using Z->mumu)

- **QCD (e+tau and mu+tau)**
  - taking SS data and apply correction for OS/SS ratio
  - W+Jets and Z->ll contamination properly subtracted
  - OS/SS ratio measured with single lepton triggers

- **W+Jets (e+tau and mu+tau)**
  - MC based shape
  - normalization taken from sidebands (reverting the Pzeta cut)

- **Fake electrons bkg (for e+mu only)**
  - mostly QCD, Z->ll, W+jets. Taken from data using fake rate method
  - uncertainty of 30% used in the fit

- **TTbar**
  - MC based shape, with normalization taken from CMS measurement
  - 12% uncertainty in the fit
  - data driven normalization for event categories using sidebands

- **Di-boson (WW/ZZ/WZ)**
  - taken from MC (30% uncertainty in the fit)

- **Z->mumu (mu+mu case)**
  - bkg normalization and shape taken with sidebands on the Likelihood based variable
Signal acceptance
Figure 25: Results for the expected (left) and observed (right) cross section, 95% upper limits, using BTagging for MSSM efficiency model for $\mu + \tau_h$, $e + \tau_h$, $e + \mu$, $\mu \mu$ and combined.
SM limits/channel

![Graphs showing SM limits for different channels and m_A (GeV/c^2)]